LEVEL

NRL Memorandum Report 4432

Physical Mechanism of the Lower-Hybrid-Drift Instability in a Collisional Plasma

J. D. Huba

Science Applications, Inc.
McLean, VA 22102

and

S. L. Ossakow

Geophysical and Plasma Dynamics Branch
Plasma Physics Division

January 30, 1981

This research was sponsored partially by the Defense Nuclear Agency under subtask S99QAXHC, work unit title, "Plasma Structure Evolution," and work unit 00002, and partially by the Office of Naval Research.

NAVAL RESEARCH LABORATORY
Washington, D.C.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NRL Memorandum Report 4432	2. GOVT ACCESSION NO. AD-A095 044	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PHYSICAL MECHANISM OF THE LOWER-HYBRID-DRIFT INSTABILITY IN A COLLISIONAL PLASMA*		5. TYPE OF REPORT & PERIOD COVERED Interim report on a continuing NRL problem. 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. D. Huba† and S. L. Ossakow		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, D.C. 20375		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61153N; RR0330244; 47-0883-0-1; and 62704H; 47-0889-0-1
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Nuclear Agency, Washington, D.C. 20305 and Office of Naval Research, Arlington, VA 22217		12. REPORT DATE January 30, 1981 13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

*This paper is based on a contributed talk entitled "Small Scale Irregularities (≲ 1m) During Equatorial Spread F" given at the Sixth International Symposium on Equatorial Aeronomy, Aguadilla, Puerto Rico, 17–24 July 1980.
†Science Applications, Inc., McLean, VA 22102

(Continues)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Lower-Hybrid-Drift instability
Small scale (≲ 1m) irregularities
Equatorial Spread F
Kinetic theory
Physical picture
Collisional, inhomogeneous plasma

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

We present a physical discussion of the lower-hybrid-drift instability in both collisionless and collisional plasmas. The instability is important since it is the most promising explanation of small-scale irregularities (i.e., ≲ 1m) observed during equatorial spread F.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

i

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

18. Supplementary Notes (Continued)

This research was sponsored partially by the Defense Nuclear Agency under subtask S99QAXHC, work unit title, "Plasma Structure Evolution," and work unit 00002, and partially by the Office of Naval Research.

CONTENTS

A

PHYSICAL MECHANISM OF THE LOWER-HYBRID-DRIFT INSTABILITY IN A COLLISIONAL PLASMA

I. INTRODUCTION

During the past several years, high-frequency radar backscatter experiments have revealed a spectrum of short-wavelength (i.e., below the ion gyroradius) irregularities during equatorial spread F (ESF). Radar backscatter observations at 50 MHz, 155 MHz and 415 MHz indicate density fluctuations exist with scale sizes of 3m, 1m, and 36 cm, respectively [FARLEY et al., 1970; WOODMAN and LAHOZ, 1976; COSTA and KELLEY, 1978a,b; HUBA et al., 1978]. Most recently, TSUNODA (1980) has observed radar backscatter from 11 cm (1320 MHz) irregularities during equatorial spread F at high altitudes, using the TRADEX radar. These observations were part of a coordinated Defense Nuclear Agency campaign at Kwajalein to study ionospheric irregularities during equatorial spread F. Sharp density gradients were observed during this campaign (M. C. KELLEY, private communication, 1980) and have been observed during past equatorial spread F events (COSTA and KELLEY, 1978a,b). The scale lengths of these gradients range from tens of meters to several hundred meters and are presumably due to primary longer wavelength instabilities such as the Rayleigh-Taylor instability. Since the typical ion gyroradius is $r_{Li} \sim 5$m, it is found that $r_{Li}/L_n \lesssim 0.2$ where L_n is the density gradient scale length.

Based upon the above evidence, it has been suggested that various drift instabilities are responsible for the short wavelength irregularities [HUBA et al., 1978; COSTA and KELLEY, 1978a,b; HUBA and OSSAKOW, 1978a,b], depending upon the wavelength observed. Although collisionless drift waves would easily be excited under these circumstances, collisional effects play an important role in the instabilities investigated thus far [HUBA and OSSAKOW, 1979a,b; SPERLING and GOLDMAN, 1980]. Specifically, the lower-hybrid-drift instability is the prime candidate to explain the 1m, 36 cm and

Manuscript submitted November 10, 1980.

11 cm irregularities. Recent research has indicated that ion collisions (i.e., ion-ion) are necessary for the destabilization of the mode during equatorial spread F [HUBA et al., 1978; HUBA and OSSAKOW, 1979a]. On the other hand, electron collisions (i.e., electron-ion, electron-electron, electron-neutral) are a stabilizing influence and place a threshold condition on the gradient scale length necessary to excite the instability [HUBA and OSSAKOW, 1979a, 1980; SPERLING and GOLDMAN, 1980]. The analysis of these collisional effects are fairly complex and, to some degree, obscure the underlying physics involved. The purpose of this paper is to present a simple discussion of the lower-hybrid-drift instability which elucidates the physical mechanism of the mode and the effects of collisions. For pedagogical purposes we consider an over-simplified model of the ionospheric plasma. Thus, the results presented (e.g., growth rates, threshold conditions) are not quantitatively accurate but are of a "back-of-the envelope" nature.

II. THEORY

A. Equilibrium and Assumptions

We consider a plasma immersed in a homogeneous, unidirectional magnetic field $B = Be_z$ with an inhomogeneous density profile $n = n_o(x)$ as shown in Fig. 1a. For simplicity we choose T_i = constant and $T_e = 0$. The influence of finite electron temperature effects is discussed in Section III. The equilibrium drift is $V = V_{di}\, e_y$ where $V_{di} = (cT_i/eB)\, \partial\ell n\, n_o/\partial x$ is the ion diamagnetic drift velocity. This drift provides the free energy to drive the instability. We point out that $V_{di} << v_i$ for ionospheric spread F conditions (here, v_i is the ion thermal velocity). Collisions are neglected in the equilibrium configuration since we are interested in time scales much shorter than the diffusion time. In the stability analysis we assume that perturbed quantities vary as $\exp\,[i\,(ky - \omega t)]$. That is, we consider flute perturbations so that $\underline{k} \cdot \underline{B} = 0$. We consider electrostatic oscillations since $\beta << 1$ and make use of the local approximation which requires $k\,L_n >> 1$ where $L_n = (\partial\ell n\, n_o/\partial x)^{-1}$. Also, we assume that $\omega << \Omega_e$ so the electrons are strongly magnetized. Finally, we assume that the ions behave as unmagnetized particles which is crucial to the instability. The ions have an equilibrium distribution function which can be described by

$$F_{io} = \left(\frac{1}{\pi v_i^2}\right)^{3/2} \exp\left[-(v_x^2 + (v_y - V_{di})^2 + v_z^2)/v_i^2\right] \tag{1}$$

B. Collisionless Plasma

It is worthwhile to first discuss the physics of the lower-hybrid-drift instability in collisionless plasmas before introducing collisional effects. The assumption of unmagnetized ions is justifiable for time scales

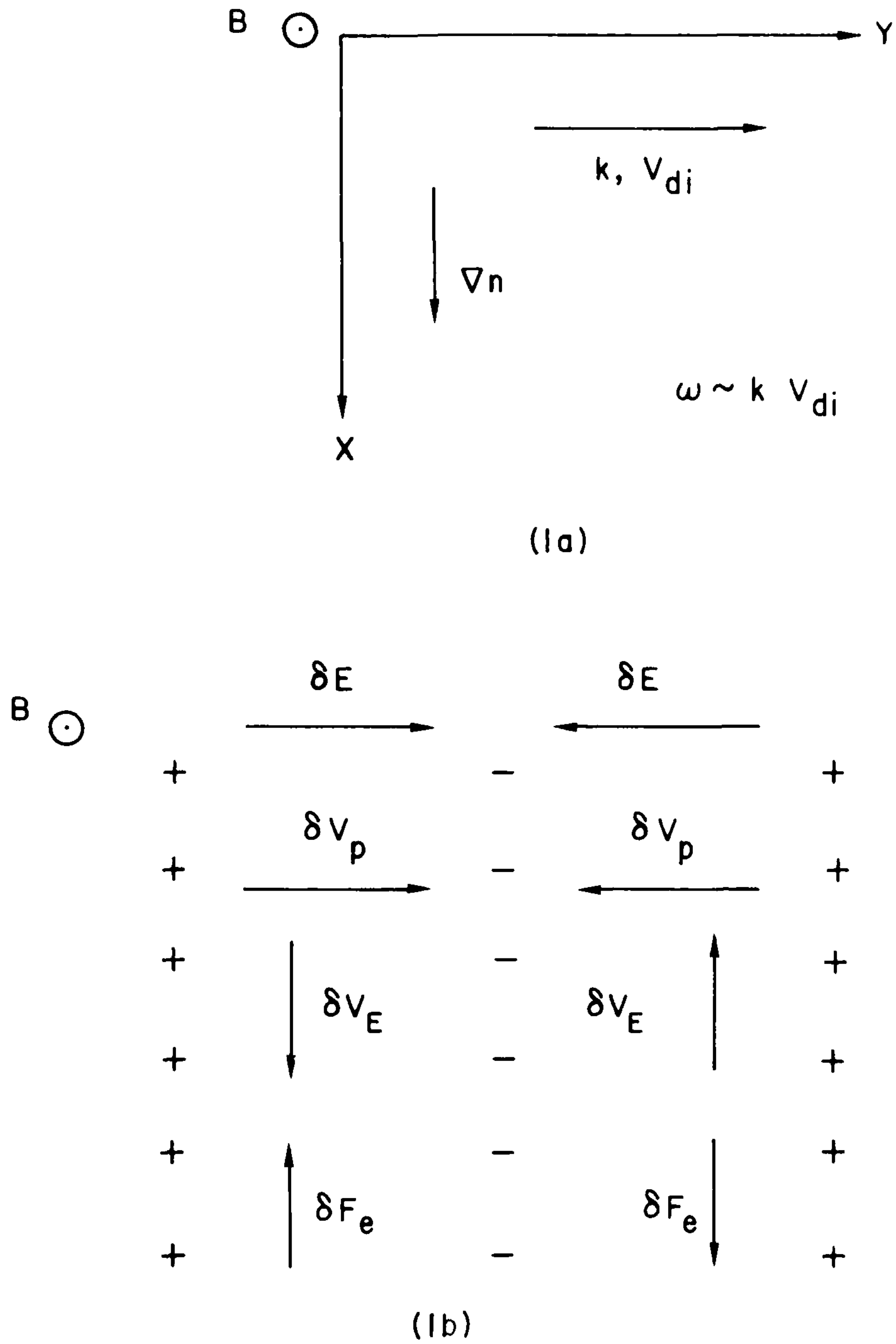

Fig. 1 — Equilibrium and electron dynamics in the wave field. (1a) Slab geometry and equilibrium configuration. (1b) Electron motion in the wave field δE. Here, δV_E is the ExB drift, δV_p is the polarization drift and δF_e is the force on electrons due to collisions.

much smaller than an ion gyroperiod (i.e., $\tau \ll \tau_i$ where $\omega = \omega_r + i\gamma$ and τ_i is the ion cyclotron period). Thus, the ions have straight line orbits on this time scale. Moreover, we consider waves such that $\omega \ll kv_i$ so that the ions are adiabatic (i.e., $\delta n_i/n_o \sim -e\phi/T_i$). The electrons, on the other hand, are strongly magnetized and execute an oscillatory $E \times B$ drift ($\delta V_E = c\delta E/B$) and a polarization drift ($\delta V_p = (c/B\omega_e)\,\partial\delta E/\partial t$) as shown in Fig. 1b. The above equilibrium gives rise to a drift wave

$$\omega = kV_{di}/(1 + k^2\rho_{es}^2) \tag{2}$$

which propagates across the magnetic field in the direction of the ion diamagnetic drift (where $\rho_{es}^2 = (T_i/m_e)/\omega_e^2$).

This drift wave can become unstable because of inverse ion Landau damping. That is, the wave can absorb energy from a group of ions moving in phase with the wave. This can be seen by noting that

$$\dot{W}_w + \dot{W}_p = 0 \tag{3}$$

where $\dot{W}_w$ and $\dot{W}_p$ are the time rates of change of the wave energy density and particle energy density, respectively. Now,

$$\dot{W}_w \propto \gamma\,\delta E^2 \tag{4}$$

and

$$\dot{W}_p = \dot{W}_{pi} \propto -\left(v_y \frac{\partial F_{io}}{\partial v_y}\right)_{v_y = \frac{\omega}{k}} \delta E^2 \tag{5}$$

so that

$$\gamma \propto \left(v_y \frac{\partial F_{io}}{\partial v_y}\right)_{v_y = \frac{\omega}{k}} \tag{6}$$

Since $\partial F_{io}/\partial v_y > 0$ for $\omega < k V_{di}$ (from Eqs. (1) and (2)) we obtain a positive growth rate (i.e., $\gamma > 0$). The growth rate is given by

$$\gamma = kV_{di} \frac{V_{di}}{v_i} \frac{k^2\rho_{es}^2}{(1+k^2\rho_{es}^2)^2} \qquad (7)$$

Note that for $k^2\rho_{es}^2 << 1$ that $\gamma \propto k^3$ while for $k^2\rho_{es}^2 >> 1$ that $\gamma \propto k^{-1}$. Growth is a maximum for $k\rho_{es} \sim 1$. Since we require $\omega >> \Omega_i$ for the ions to be unmagnetized, a threshold is placed on the diamagnetic drift (or density gradient scale length) which is roughly given by $V_{di}/v_i > (m_e/m_i)^{1/4}$ or $L_n/r_{Li} < (m_i/m_e)^{1/4}$ where r_{Li} is the mean ion Larmor radius.

C. Collisional Plasma

1. Ion Collisions (ion-ion)

As just noted, a threshold condition exists on the density gradient scale length to excite the mode in collisionless plasmas. For ionospheric dontions, the threshold is approximately $L_n < 30$m which represents a very sharp density gradient. Such sharp gradients are rarely observed [COSTA AND KELLEY, 1978a]. Superficially, this would appear to limit the applicability of this mode to spread F; however, the role of ion-ion collisions alters the threshold condition. In the spirit of the paper, we simply describe how ion-ion collisions influence the instability rather than present a mathematical analysis. A detailed derivation can be found elsewhere (HUBA and OSSAKOW, 1979a).

In order to excite the instability ions must be in resonance with a drift wave propagating perpendicular to the magnetic. Clearly if the ions are magnetized, they are tied to the field lines and cannot move across the field. However, ion-ion collisions provide a mechanism that allows ions to move across magnetic field lines. That is, ions can diffuse a distance

$L_D \sim (\nu_{ii}/\Omega_i)^{1/2} r_{Li}$ in one gyro period. If this distance is greater than a wavelength then the ion's cyclotron behavior is lost and the ions behave as unmagnetized particles. The ion demagnetization condition is

$$\frac{\nu_{ii}}{\Omega_i} k^2 r_{Li}^2 \sim 1 \tag{8}$$

Since maximum growth occurs for $k^2 \rho_{es}^2 \sim 1$, we require $\nu_{ii}/\Omega_i > m_e/m_i \sim 10^{-5}$ for instability to occur in an O^+ plasma. Equation (8) is easily satisfied for typical spread F conditions.

2. Electron Collisions (electron-ion, electron-neutral, electron-electron)

In collisionless plasmas, the only energy exchange occurs between the wave and the resonant ions since the electrons are nonresonant. However, electron collisions introduce additional dissipation which modifies Eq. (5). As noted earlier, electrons execute an oscillatory ExB and polarization drift motion due to the wave field (Fig. 1b). The polarization drift is roughly given by $\delta V_p \sim (\omega/\Omega_e)\, \delta V_E$ which for the waves in question implies $\delta V_p \ll \delta V_E$. Thus, the dominant electron motion is the $\underline{E}\times\underline{B}$ drift. Because of collisions, a force is exerted on the electrons; approximately given by $\delta F_e \sim -m_e \nu_e \delta V_E$ where ν_e contains e-e, e-i and e-n collisions. The rate of energy absorption by the electrons is roughly $\dot{W}_{pe} \sim -\delta \underset{\sim}{F}_e \cdot \underset{\sim}{v} \propto \nu_e\, \delta E^2$. The total change in particle energy is

$$\dot{W}_p \propto \left[- \left(v_y \frac{\partial F_{io}}{\partial v_y} \right)_{v_y = \omega/k} + \nu_e \right] \delta E^2 \tag{9}$$

We obtain from Eq. (3) and (4)

$$\gamma \propto \left[\left(v_y \frac{\partial F_{io}}{\partial v_y}\right)_{v_y = \frac{\omega}{k}} - \nu_e\right] \tag{10}$$

Thus, resonant ions give energy to the wave while electrons absorb energy from the wave because of collisions. Instability occurs when $\gamma > 0$ which requires (approximately)

$$\frac{V_{di}}{v_i} > \left(\frac{\nu_e}{kv_i}\right)^{1/2} \tag{11}$$

or

$$L_n < r_{Li}\left(\frac{kv_i}{\nu_e}\right)^{1/2} \tag{12}$$

III. DISCUSSION

Our purpose has been to give a physical discussion of the lower-hybrid-drift instability. This instability is presently the most promising explanation of small-scale irregularities ($\lesssim 1$ m) observed during equatorial spread F. The key features of the mode are:

1. The instability excites a drift wave propagating across the magnetic field.
2. The wave is driven by the free energy provided by the density gradient and the energy exchange occurs via an ion-wave resonance.
3. For an ion-wave resonance to occur the ions must be able to move across the magnetic field. This is possible under two conditions:
   a. In a collisionless plasma, one considers time scales such that $\gamma > \Omega_i$.
   b. In a collisional plasma, ion-ion collisions allow the ions to move across the magnetic field. The condition is $(\nu_{ii}/\Omega_i)k^2 r_{Li}{}^2 \gtrsim 1$.
4. Electron collisions allow the electrons to absorb energy from the wave and therefore provide a damping mechanism.
5. An approximate threshold condition for instability is:
   a. Collisionless plasma

   $$L_n < r_{Li} (m_i/m_e)^{1/4}$$

   b. Collisional plasma

   $$L_n < r_{Li} (kv_i/\nu_e)^{1/2}$$

Finally, we mention that inclusion of finite electron temperature effects introduces (i) finite electron Larmor radius effects which modify the dispersion properties of the mode and (ii) an electron diamagnetic drift which increases the free energy of the initial equilibrium.

ACKNOWLEDGMENTS

This work was supported by the Defense Nuclear Agency and the Office of Naval Research. We thank J.F. Drake for helpful discussions.

REFERENCES

COSTA, E. and KELLEY, M. C.	1978	J. Geophys. Res., 83, 4359.
COSTA, E. and KELLEY, M. C.	1978b	J. Geophys. Res., 83, 4365.
FARLEY, D.T., BALSLEY, B. B., WOODMAN, R.F. and MCLURE, J.P.	1970	J. Geophys. Res., 75, 7199.
HUBA, J. D., CHATURVEDI, P. K., OSSAKOW, S.L. and TOWLE, D.M.	1978	Geophys. Res. Lett., 5, 695.
HUBA, J. D. and OSSAKOW, S. L.	1979a	Phys. Fluids, 22, 1349.
HUBA, J. D. and OSSAKOW, S. L.	1979b	J. Geophys. Res., 84, 6697.
HUBA, J. D. and OSSAKOW, S. L.	1980	To be published in J. Geophys. Res.
SPERLING, J.L. and GOLDMAN, S.R.	1980	J. Geophys. Res., 85, 3494.
TSUNODA, R.	1980	Geophys. Res. Lett., 7, 848.
WOODMAN, R.F. and LAHOZ, C.	1976	J. Geophys. Res., 81, 5447.

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

ASSISTANT SECRETARY OF DEFENSE
COMM, CMD, CONT & INTELL
WASHINGTON, D.C. 20301
01CY ATTN J. BABCOCK
01CY ATTN M. EPSTEIN

ASSISTANT TO THE SECRETARY OF DEFENSE
ATOMIC ENERGY
WASHINGTON, D.C. 20301
01CY ATTN EXECUTIVE ASSISTANT

DIRECTOR
COMMAND CONTROL TECHNICAL CENTER
PENTAGON RM BE 685
WASHINGTON, D.C. 20301
01CY ATTN C-650
01CY ATTN C-312 R. MASON

DIRECTOR
DEFENSE ADVANCED RSCH PROJ AGENCY
ARCHITECT BUILDING
1400 WILSON BLVD.
ARLINGTON, VA. 22209
01CY ATTN NUCLEAR MONITORING RESEARCH
01CY ATTN STRATEGIC TECH OFFICE

DEFENSE COMMUNICATION ENGINEER CENTER
1860 WIEHLE AVENUE
RESTON, VA. 22090
01CY ATTN CODE R820
01CY ATTN CODE R410 JAMES W. MCLEAN
01CY ATTN CODE R720 J. WORTHINGTON

DIRECTOR
DEFENSE COMMUNICATIONS AGENCY
WASHINGTON, D.C. 20305
(ADR CNWDI: ATTN CODE 240 FOR)
01CY ATTN CODE 101B

DEFENSE TECHNICAL INFORMATION CENTER
CAMERON STATION
ALEXANDRIA, VA. 22314
(12 COPIES IF OPEN PUBLICATION, OTHERWISE 2 COPIES)
12CY ATTN TC

DIRECTOR
DEFENSE INTELLIGENCE AGENCY
WASHINGTON, D.C. 20301
01CY ATTN DT-1B
01CY ATTN DB-4C E. O'FARRELL
01CY ATTN DIAAP A. WISE
01CY ATTN DIAST-5
01CY ATTN DT-1BZ R. MORTON
01CY ATTN HQ-TR J. STEWART
01CY ATTN W. WITTIG DC-7D

DIRECTOR
DEFENSE NUCLEAR AGENCY
WASHINGTON, D.C. 20305
01CY ATTN STVL
04CY ATTN TITL
01CY ATTN DDST
03CY ATTN RAAE

COMMANDER
FIELD COMMAND
DEFENSE NUCLEAR AGENCY
KIRTLAND AFB, NM 87115
01CY ATTN FCPR

DIRECTOR
INTERSERVICE NUCLEAR WEAPONS SCHOOL
KIRTLAND AFB, NM 87115
01CY ATTN DOCUMENT CONTROL

JOINT CHIEFS OF STAFF
WASHINGTON, D.C. 20301
01CY ATTN J-3 WWMCCS EVALUATION OFFICE

DIRECTOR
JOINT STRAT TGT PLANNING STAFF
OFFUTT AFB
OMAHA, NB 68113
01CY ATTN JLTW-2
01CY ATTN JPST G. GOETZ

CHIEF
LIVERMORE DIVISION FLD COMMAND DNA
DEPARTMENT OF DEFENSE
LAWRENCE LIVERMORE LABORATORY
P. O. BOX 808
LIVERMORE, CA 94550
01CY ATTN FCPRL

DIRECTOR
NATIONAL SECURITY AGENCY
DEPARTMENT OF DEFENSE
FT. GEORGE G. MEADE, MD 20755
01CY ATTN JOHN SKILLMAN R52
01CY ATTN FRANK LEONARD
01CY ATTN W14 PAT CLARK
01CY ATTN OLIVER H. BARTLETT W32
01CY ATTN R5

COMMANDANT
NATO SCHOOL (SHAPE)
APO NEW YORK 09172
01CY ATTN U.S. DOCUMENTS OFFICER

UNDER SECY OF DEF FOR RSCH & ENGRG
DEPARTMENT OF DEFENSE
WASHINGTON, D.C. 20301
01CY ATTN STRATEGIC & SPACE SYSTEMS (OS)

WWMCCS SYSTEM ENGINEERING ORG
WASHINGTON, D.C. 20305
01CY ATTN R. CRAWFORD

COMMANDER/DIRECTOR
ATMOSPHERIC SCIENCES LABORATORY
U.S. ARMY ELECTRONICS COMMAND
WHITE SANDS MISSILE RANGE, NM 88002
01CY ATTN DELAS-EO F. NILES

DIRECTOR
BMD ADVANCED TECH CTR
HUNTSVILLE OFFICE
P. O. BOX 1500
HUNTSVILLE, AL 35807
01CY ATTN ATC-T MELVIN T. CAPPS
01CY ATTN ATC-O W. DAVIES
01CY ATTN ATC-R DON RUSS

PROGRAM MANAGER
BMD PROGRAM OFFICE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333
01CY ATTN DACS-BMT J. SHEA

CHIEF C-E SERVICES DIVISION
U.S. ARMY COMMUNICATIONS CMD
PENTAGON RM 1B269
WASHINGTON, D.C. 20310
01CY ATTN C-E-SERVICES DIVISION

COMMANDER
FRADCOM TECHNICAL SUPPORT ACTIVITY
DEPARTMENT OF THE ARMY
FORT MONMOUTH, N.J. 07703
01CY ATTN DRSEL-NL-RD H. BENNET
01CY ATTN DRSEL-PL-ENV H. BOMKE
01CY ATTN J. E. QUIGLEY

COMMANDER
HARRY DIAMOND LABORATORIES
DEPARTMENT OF THE ARMY
2800 POWDER MILL ROAD
ADELPHI, MD 20783
(CNWDI-INNER ENVELOPE: ATTN: DELHD-RBH)
01CY ATTN DELHD-TI M. WEINER
01CY ATTN DELHD-RB R. WILLIAMS
01CY ATTN DELHD-NP F. WIMENITZ
01CY ATTN DELHD-NP C. MOAZED

COMMANDER
U.S. ARMY COMM-ELEC ENGRG INSTAL AGY
FT. HUACHUCA, AZ 85613

01CY ATTN CCC-EMEO GEORGE LANE

COMMANDER
U.S. ARMY FOREIGN SCIENCE & TECH CTR
220 7TH STREET, NE
CHARLOTTESVILLE, VA 22901
01CY ATTN DRXST-SD
01CY ATTN R. JONES

COMMANDER
U.S. ARMY MATERIEL DEV & READINESS CMD
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333
01CY ATTN DRCLDC J. A. BENDER

COMMANDER
U.S. ARMY NUCLEAR AND CHEMICAL AGENCY
7500 BACKLICK ROAD
BLDG 2073
SPRINGFIELD, VA 22150
01CY ATTN LIBRARY

DIRECTOR
U.S. ARMY BALLISTIC RESEARCH LABS
ABERDEEN PROVING GROUND, MD 21005
01CY ATTN TECH LIB EDWARD BAICY

COMMANDER
U.S. ARMY SATCOM AGENCY
FT. MONMOUTH, NJ 07703
01CY ATTN DOCUMENT CONTROL

COMMANDER
U.S. ARMY MISSILE INTELLIGENCE AGENCY
REDSTONE ARSENAL, AL 35809
01CY ATTN JIM GAMBLE

DIRECTOR
U.S. ARMY TRADOC SYSTEMS ANALYSIS ACTIVITY
WHITE SANDS MISSILE RANGE, NM 88002
01CY ATTN ATAA-SA
01CY ATTN TCC/F. PAYAN JR.
01CY ATTN ATAA-TAC LTC J. HESSE

COMMANDER
NAVAL ELECTRONIC SYSTEMS COMMAND
WASHINGTON, D.C. 20360
01CY ATTN NAVALEX 034 T. HUGHES
01CY ATTN PME 117
01CY ATTN PME 117-T
01CY ATTN CODE 5011

COMMANDING OFFICER
NAVAL INTELLIGENCE SUPPORT CTR
4301 SUITLAND ROAD, BLDG. 5
WASHINGTON, D.C. 20390
01CY ATTN MR. DUBBIN STIC 12
01CY ATTN NISC-50
01CY ATTN CODE 5404 [illegible]. GALET

COMMANDER
NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CA 92152
01CY ATTN CODE 532 W. MOLER
01CY ATTN CODE 0230 C. [illegible]
01CY ATTN CODE 81 R. EASTMAN

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON, D.C. 20375
01CY ATTN CODE 4700 T. P. COFFEY (25 CYS IF UN, 1 CY IF CLASS)
01CY ATTN CODE 4701 JACK D. BROWN
01CY ATTN CODE 4780 BRANCH HEAD (150 CYS IF UN, 1 CY IF CLASS)
01CY ATTN CODE 7500 HQ COMM DIR BRUCE WALD
01CY ATTN CODE 7550 J. DAVIS
01CY ATTN CODE 7580
01CY ATTN CODE 7551
01CY ATTN CODE 7555
01CY ATTN CODE 4730 E. MCLEAN
01CY ATTN CODE 4127 C. JOHNSON

COMMANDER
NAVAL SEA SYSTEMS COMMAND
WASHINGTON, D.C. 20362
01CY ATTN CAPT R. PITKIN

COMMANDER
NAVAL SPACE SURVEILLANCE SYSTEM
DAHLGREN, VA 22448
01CY ATTN CAPT J. H. BURTON

OFFICER-IN-CHARGE
NAVAL SURFACE WEAPONS CENTER
WHITE OAK, SILVER SPRING, MD 20910
01CY ATTN CODE F31

DIRECTOR
STRATEGIC SYSTEMS PROJECT OFFICE
DEPARTMENT OF THE NAVY
WASHINGTON, D.C. 20376
01CY ATTN NSP-2141
01CY ATTN NSSP-2722 FRED WIMBERLY

NAVAL SPACE SYSTEM ACTIVITY
P. O. BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES, CALIF. 90009
01CY ATTN A. B. HAZZARD

COMMANDER
NAVAL SURFACE WEAPONS CENTER
DAHLGREN LABORATORY
DAHLGREN, VA 22448
01CY ATTN CODE DF-14 R. BUTLER

COMMANDING OFFICER
NAVY SPACE SYSTEMS ACTIVITY
P.O. BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES, CA. 90009
01CY ATTN CODE 52

OFFICE OF NAVAL RESEARCH
ARLINGTON, VA 22217
01CY ATTN CODE 465
01CY ATTN CODE 461
01CY ATTN CODE 402
01CY ATTN CODE 420
01CY ATTN CODE 421

COMMANDER
AEROSPACE DEFENSE COMMAND/DC
DEPARTMENT OF THE AIR FORCE
ENT AFB, CO 80912
01CY ATTN DC MR. LONG

COMMANDER
AEROSPACE DEFENSE COMMAND/XPD
DEPARTMENT OF THE AIR FORCE
ENT AFB, CO 80912
01CY ATTN XPDQQ
01CY ATTN XP

AIR FORCE GEOPHYSICS LABORATORY
HANSCOM AFB, MA 01731
01CY ATTN OPR HAROLD GARDNER
01CY ATTN OPR-1 JAMES C. ULWICK
01CY ATTN LKB KENNETH S. W. CHAMPION
01CY ATTN OPR ALVA T. STAIR
01CY ATTN PHP JULES AARONS
01CY ATTN PHD JURGEN BUCHAU
01CY ATTN PHD JOHN P. MULLEN

AF WEAPONS LABORATORY
KIRTLAND AFB, NM 87117
01CY ATTN SUL
01CY ATTN CA ARTHUR H. GUENTHER
01CY ATTN DYC CAPT J. BARRY
01CY ATTN DYC JOHN M. KAMM
01CY ATTN DYT CAPT MARK A. FRY
01CY ATTN DES MAJ GARY GANONG
01CY ATTN DYC J. JANNI

AFTAC
PATRICK AFB, FL 32925
01CY ATTN TF/MAJ WILEY
01CY ATTN TN

AIR FORCE AVIONICS LABORATORY
WRIGHT-PATTERSON AFB, OH 45433
01CY ATTN AAD WADE HUNT
01CY ATTN AAD ALLEN JOHNSON

DEPUTY CHIEF OF STAFF
RESEARCH, DEVELOPMENT, & ACQ
DEPARTMENT OF THE AIR FORCE
WASHINGTON, D.C. 20330
01CY ATTN AFRDQ

HEADQUARTERS
ELECTRONIC SYSTEMS DIVISION/XR
DEPARTMENT OF THE AIR FORCE
HANSCOM AFB, MA 01731
01CY ATTN XR J. DEAS

HEADQUARTERS
ELECTRONIC SYSTEMS DIVISION/YSEA
DEPARTMENT OF THE AIR FORCE
HANSCOM AFB, MA 01731
01CY ATTN YSEA

HEADQUARTERS
ELECTRONIC SYSTEMS DIVISION/DC
DEPARTMENT OF THE AIR FORCE
HANSCOM AFB, MA 01731
01CY ATTN DCKC MAJ J.C. CLARK

COMMANDER
FOREIGN TECHNOLOGY DIVISION, AFSC
WRIGHT-PATTERSON AFB, OH 45433
01CY ATTN NICD LIBRARY
01CY ATTN ETDP B. BALLARD

COMMANDER
ROME AIR DEVELOPMENT CENTER, AFSC
GRIFFISS AFB, NY 13441
01CY ATTN DOC LIBRARY/TSLD
01CY ATTN OCSE V. COYNE

SAMSO/SZ
POST OFFICE BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES, CA 90009
(SPACE DEFENSE SYSTEMS)
01CY ATTN SZJ

STRATEGIC AIR COMMAND/XPFS
OFFUTT AFB, NB 68113
01CY ATTN XPFS MAJ B. STEPHAN
01CY ATTN ADWATE MAJ BRUCE BAUER
01CY ATTN NRT
01CY ATTN DOK CHIEF SCIENTIST

SAMSO/SK
P. O. BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES, CA 90009
01CY ATTN SKA (SPACE COMM SYSTEMS) M. CLAVIN

SAMSO/MN
NORTON AFB, CA 92409
(MINUTEMAN)
01CY ATTN MNNL LTC KENNEDY

COMMANDER
ROME AIR DEVELOPMENT CENTER, AFSC
HANSCOM AFB, MA 01731
01CY ATTN EEP A. LORENTZEN

DEPARTMENT OF ENERGY
ALBUQUERQUE OPERATIONS OFFICE
P. O. BOX 5400
ALBUQUERQUE, NM 87115
01CY ATTN DOC CON FOR D. SHERWOOD

DEPARTMENT OF ENERGY
LIBRARY ROOM G-042
WASHINGTON, D.C. 20545
01CY ATTN DOC CON FOR A. LABOWITZ

EG&G, INC.
LOS ALAMOS DIVISION
P. O. BOX 809
LOS ALAMOS, NM 85544
01CY ATTN DOC CON FOR J. BREEDLOVE

UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE LABORATORY
P. O. BOX 808
LIVERMORE, CA 94550
01CY ATTN DOC CON FOR TECH INFO DEPT
01CY ATTN DOC CON FOR L-389 R. OTT
01CY ATTN DOC CON FOR L-31 R. HAGER
01CY ATTN DOC CON FOR L-46 F. SEWARD

LOS ALAMOS SCIENTIFIC LABORATORY
P. O. BOX 1663
LOS ALAMOS, NM 87545
01CY ATTN DOC CON FOR J. WOLCOTT
01CY ATTN DOC CON FOR R. F. TASCHEK
01CY ATTN DOC CON FOR E. JONES
01CY ATTN DOC CON FOR J. MALIK
01CY ATTN DOC CON FOR R. JEFFRIES
01CY ATTN DOC CON FOR J. ZINN
01CY ATTN DOC CON FOR P. KEATON
01CY ATTN DOC CON FOR D. WESTERVELT

SANDIA LABORATORIES
P. O. BOX 5800
ALBUQUERQUE, NM 87115
01CY ATTN DOC CON FOR J. MARTIN
01CY ATTN DOC CON FOR W. BROWN
01CY ATTN DOC CON FOR A. THORNBROUGH
01CY ATTN DOC CON FOR T. WRIGHT
01CY ATTN DOC CON FOR D. DAHLGREN
01CY ATTN DOC CON FOR 3141
01CY ATTN DOC CON FOR SPACE PROJECT DIV

SANDIA LABORATORIES
LIVERMORE LABORATORY
P. O. BOX 969
LIVERMORE, CA 94550
01CY ATTN DOC CON FOR B. MURPHEY
01CY ATTN DOC CON FOR T. COOK

OFFICE OF MILITARY APPLICATION
DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20545
01CY ATTN DOC CON FOR D. GALE

OTHER GOVERNMENT

CENTRAL INTELLIGENCE AGENCY
ATTN RD/SI, RM 5G48, HQ BLDG
WASHINGTON, D.C. 20505
01CY ATTN OSI/PSID RM 5F 19

DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234
(ALL CORRES: ATTN SEC OFFICER FOR)
01CY ATTN R. MOORE

INSTITUTE FOR TELECOM SCIENCES
NATIONAL TELECOMMUNICATIONS & INFO ADMIN
BOULDER, CO 80303
01CY ATTN A. JEAN (UNCLASS ONLY)
01CY ATTN W. UTLAUT
01CY ATTN D. CROMBIE
01CY ATTN L. BERRY

NATIONAL OCEANIC & ATMOSPHERIC ADMIN
ENVIRONMENTAL RESEARCH LABORATORIES
DEPARTMENT OF COMMERCE
BOULDER, CO 80302
01CY ATTN R. GRUBB
01CY ATTN AERONOMY LAB G. REID

DEPARTMENT OF DEFENSE CONTRACTORS

AEROSPACE CORPORATION
P. O. BOX 92957
LOS ANGELES, CA 90009
01CY ATTN I. GARFUNKEL
01CY ATTN T. SALMI
01CY ATTN V. JOSEPHSON
01CY ATTN S. BOWER
01CY ATTN N. STOCKWELL
01CY ATTN D. OLSEN

01CY ATTN SMFA FOR PWW

ANALYTICAL SYSTEMS ENGINEERING CORP
5 OLD CONCORD ROAD
BURLINGTON, MA 01803
01CY ATTN RADIO SCIENCES

BERKELEY RESEARCH ASSOCIATES, INC.
P. O. BOX 983
BERKELEY, CA 94701
01CY ATTN J. WORKMAN

BOEING COMPANY, THE
P. O. BOX 3707
SEATTLE, WA 98124
01CY ATTN G. KEISTER
01CY ATTN D. MURRAY
01CY ATTN G. HALL
01CY ATTN J. KENNEY

CALIFORNIA AT SAN DIEGO, UNIV OF
P. O. Box 6049
San Diego. CA 92106

BROWN ENGINEERING COMPANY, INC.
CUMMINGS RESEARCH PARK
HUNTSVILLE, AL 35807
01CY ATTN ROMEO A. DELIBERIS

CHARLES STARK DRAPER LABORATORY, INC.
555 TECHNOLOGY SQUARE
CAMBRIDGE, MA 02139
01CY ATTN D. B. COX
01CY ATTN J. P. GILMORE

COMPUTER SCIENCES CORPORATION
6565 ARLINGTON BLVD
FALLS CHURCH, VA 22046
01CY ATTN H. BLANK
01CY ATTN JOHN SPOOR
01CY ATTN C. NAIL

COMSAT LABORATORIES
LINTHICUM ROAD
CLARKSBURG, MD 20734
01CY ATTN G. HYDE

CORNELL UNIVERSITY
DEPARTMENT OF ELECTRICAL ENGINEERING
ITHACA, NY 14850
01CY ATTN D. T. FARLEY JR

ELECTROSPACE SYSTEMS, INC.
BOX 1359
RICHARDSON, TX 75080
01CY ATTN H. LOGSTON
01CY ATTN SECURITY (PAUL PHILLIPS)

ESL INC.
495 JAVA DRIVE
SUNNYVALE, CA 94086
01CY ATTN J. ROBERTS
01CY ATTN JAMES MARSHALL
01CY ATTN C. W. PRETTIE

FORD AEROSPACE & COMMUNICATIONS CORP
3939 FABIAN WAY
PALO ALTO, CA 94303
01CY ATTN J. T. MATTINGLEY

GENERAL ELECTRIC COMPANY
SPACE DIVISION
VALLEY FORGE SPACE CENTER
GODDARD BLVD KING OF PRUSSIA
P. O. BOX 8555
PHILADELPHIA, PA 19101
01CY ATTN M. H. BORTNER SPACE SCI LAB

GENERAL ELECTRIC COMPANY
P. O. BOX 1122
SYRACUSE, NY 13201
01CY ATTN F. REIBERT

GENERAL ELECTRIC COMPANY
TEMPO-CENTER FOR ADVANCED STUDIES
816 STATE STREET (P.O. DRAWER QQ)
SANTA BARBARA, CA 93102
01CY ATTN DASIAC
01CY ATTN DON CHANDLER
01CY ATTN TOM BARRETT
01CY ATTN TIM STEPHANS
01CY ATTN WARREN S. KNAPP
01CY ATTN WILLIAM MCNAMARA
01CY ATTN B. GAMBILL
01CY ATTN MACK STANTON

GENERAL ELECTRIC TECH SERVICES CO., INC.
HMES
COURT STREET
SYRACUSE, NY 13201
01CY ATTN G. MILLMAN

GENERAL RESEARCH CORPORATION
SANTA BARBARA DIVISION
P. O. BOX 6770
SANTA BARBARA, CA 93111
01CY ATTN JOHN ISE JR
01CY ATTN JOEL GARBARINO

GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS, AK 99701
(ALL CLASS ATTN: SECURITY OFFICER)
01CY ATTN T. N. DAVIS (UNCL ONLY)
01CY ATTN NEAL BROWN (UNCL ONLY)
01CY ATTN TECHNICAL LIBRARY

GTE SYLVANIA, INC.
ELECTRONICS SYSTEMS GRP-EASTERN DIV
77 A STREET
NEEDHAM, MA 02194
01CY ATTN MARSHAL CROSS

ILLINOIS, UNIVERSITY OF
DEPARTMENT OF ELECTRICAL ENGINEERING
URBANA, IL 61803
01CY ATTN K. YEH

ILLINOIS, UNIVERSITY OF
107 COBLE HALL
801 S. WRIGHT STREET
URBANA, IL 60580
(ALL CORRES ATTN SECURITY SUPERVISOR FOR)
01CY ATTN K. YEH

INSTITUTE FOR DEFENSE ANALYSES
400 ARMY-NAVY DRIVE
ARLINGTON, VA 22202
01CY ATTN J. M. AEIN
01CY ATTN ERNEST BAUER
01CY ATTN HANS WOLFHARD
01CY ATTN JOEL BENGSTON

HSS, INC.
2 ALFRED CIRCLE
BEDFORD, MA 01730
01CY ATTN DONALD HANSEN

INTL TEL & TELEGRAPH CORPORATION
500 WASHINGTON AVENUE
NUTLEY, NJ 07110
01CY ATTN TECHNICAL LIBRARY

JAYCOR
1401 CAMINO DEL MAR
DEL MAR, CA 92014
01CY ATTN S. R. GOLDMAN

JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
JOHNS HOPKINS ROAD
LAUREL, MD 20810
01CY ATTN DOCUMENT LIBRARIAN
01CY ATTN THOMAS POTEMRA
01CY ATTN JOHN DASSOULAS

LOCKHEED MISSILES & SPACE CO INC
P. O. BOX 504
SUNNYVALE, CA 94088
01CY ATTN DEPT 60-12
01CY ATTN D. R. CHURCHILL

LOCKHEED MISSILES AND SPACE CO INC
3251 HANOVER STREET
PALO ALTO, CA 94304
01CY ATTN MARTIN WALT DEPT 52-10
01CY ATTN RICHARD G. JOHNSON DEPT 52-12
01CY ATTN W. L. IMHOF DEPT 52-12

KAMAN SCIENCES CORP
P. O. BOX 7463
COLORADO SPRINGS, CO 80933
01CY ATTN T. MEAGHER

LINKABIT CORP
10453 ROSELLE
SAN DIEGO, CA 92121
01CY ATTN IRWIN JACOBS

M.I.T. LINCOLN LABORATORY
P. O. BOX 73
LEXINGTON, MA 02173
01CY ATTN DAVID M. TOWLE
01CY ATTN P. WALDRON
01CY ATTN L. LOUGHLIN
01CY ATTN D. CLARK

MARTIN MARIETTA CORP
ORLANDO DIVISION
P. O. BOX 5837
ORLANDO, FL 32805
01CY ATTN R. HEFFNER

MCDONNELL DOUGLAS CORPORATION
5301 BOLSA AVENUE
HUNTINGTON BEACH, CA 92647
01CY ATTN N. HARRIS
01CY ATTN J. MOULE
01CY ATTN GEORGE MROZ
01CY ATTN W. OLSON
01CY ATTN R. W. HALPRIN
01CY ATTN TECHNICAL LIBRARY SERVICES

MISSION RESEARCH CORPORATION
735 STATE STREET
SANTA BARBARA, CA 93101
01CY ATTN R. FISCHER
01CY ATTN W. F. CREVIER
01CY ATTN STEVEN L. GUTSCHE
01CY ATTN D. SAPPENFIELD
01CY ATTN R. BOGUSCH
01CY ATTN R. HENDRICK
01CY ATTN RALPH KILB
01CY ATTN DAVE SOWLE
01CY ATTN F. FAJEN
01CY ATTN M. SCHEIBE
01CY ATTN CONRAD L. LONGMIRE
01CY ATTN WARREN A. SCHLUETER

MITRE CORPORATION, THE
P. O. BOX 208
BEDFORD, MA 01730
01CY ATTN JOHN MORGANSTERN
01CY ATTN G. HARDING
01CY ATTN C. E. CALLAHAN

MITRE CORP
WESTGATE RESEARCH PARK
1820 DOLLY MADISON BLVD
MCLEAN, VA 22101
01CY ATTN W. HALL
01CY ATTN W. FOSTER

PACIFIC-SIERRA RESEARCH CORP
1456 CLOVERFIELD BLVD.
SANTA MONICA, CA 90404
01CY ATTN E. C. FIELD JR

PENNSYLVANIA STATE UNIVERSITY
IONOSPHERE RESEARCH LAB
318 ELECTRICAL ENGINEERING EAST
UNIVERSITY PARK, PA 16802
(NO CLASSIFIED TO THIS ADDRESS)
01CY ATTN IONOSPHERIC RESEARCH LAB

PHOTOMETRICS, INC.
442 MARRETT ROAD
LEXINGTON, MA 02173
01CY ATTN IRVING L. KOFSKY

PHYSICAL DYNAMICS INC.
P. O. BOX 3027
BELLEVUE, WA 98009
01CY ATTN E. J. FREMOUW

PHYSICAL DYNAMICS INC.
P. O. BOX 10367
OAKLAND, CA. 94610
ATTN: A. THOMSON

R & D ASSOCIATES
P. O. BOX 9695
MARINA DEL REY, CA 90291
01CY ATTN FORREST GILMORE
01CY ATTN BRYAN GABBARD
01CY ATTN WILLIAM B. WRIGHT JR
01CY ATTN ROBERT F. LELEVIER
01CY ATTN WILLIAM J. KARZAS
01CY ATTN H. ORY
01CY ATTN C. MACDONALD
01CY ATTN R. TURCO

RAND CORPORATION, THE
1700 MAIN STREET
SANTA MONICA, CA 90406
01CY ATTN CULLEN CRAIN
01CY ATTN ED BEDROZIAN

RIVERSIDE RESEARCH INSTITUTE
80 WEST END AVENUE
NEW YORK, NY 10023
01CY ATTN VINCE TRAPANI

SCIENCE APPLICATIONS, INC.
P. O. BOX 2351
LA JOLLA, CA 92038
01CY ATTN LEWIS M. LINSON
01CY ATTN DANIEL A. HAMLIN
01CY ATTN D. SACHS
01CY ATTN E. A. STRAKER
01CY ATTN CURTIS A. SMITH
01CY ATTN JACK MCDOUGALL

RAYTHEON CO.
528 BOSTON POST ROAD
SUDBURY, MA 01776
01CY ATTN BARBARA ADAMS

Science Applications, Incorporated
1710 Goodridge Drive
McLean, VA 22102
Attn: J. Cockayne

Lockheed Missile & Space Co.,Inc.
Huntsville Research & Engr. Ctr.
4800 Bradford Drive
Huntsville, Alabama 35807
Attn: Dale H. Davis

SRI INTERNATIONAL
333 RAVENSWOOD AVENUE
MENLO PARK, CA 94025
01CY ATTN DONALD NEILSON
01CY ATTN ALAN BURNS
01CY ATTN G. SMITH
01CY ATTN L. L. COBB
01CY ATTN DAVID A. JOHNSON
01CY ATTN WALTER G. CHESNUT
01CY ATTN CHARLES L. RINO
01CY ATTN WALTER JAYE
01CY ATTN M. BARON
01CY ATTN RAY L. LEADABRAND
01CY ATTN G. CARPENTER
01CY ATTN G. PRICE
01CY ATTN J. PETERSON
01CY ATTN R. HAKE, JR.
01CY ATTN V. GONZALES
01CY ATTN D. MCDANIEL

TECHNOLOGY INTERNATIONAL CORP
75 WIGGINS AVENUE
BEDFORD, MA 01730
01CY ATTN W. P. BOQUIST

TRW DEFENSE & SPACE SYS GROUP
ONE SPACE PARK
REDONDO BEACH, CA 90278
01CY ATTN R. K. PLEBUCH
01CY ATTN S. ALTSCHULER
01CY ATTN D. DEE

VISIDYNE, INC.
19 THIRD AVENUE
NORTH WEST INDUSTRIAL PARK
BURLINGTON, MA 01803
01CY ATTN CHARLES HUMPHREY
01CY ATTN J. W. CARPENTER

IONOSPHERIC MODELING DISTRIBUTION LIST
UNCLASSIFIED ONLY

PLEASE DISTRIBUTE ONE COPY TO EACH OF THE FOLLOWING PEOPLE:

ADVANCED RESEARCH PROJECTS AGENCY (ARPA)
STRATEGIC TECHNOLOGY OFFICE
ARLINGTON, VIRGINIA

CAPT. DONALD M. LEVINE

NAVAL RESEARCH LABORATORY
WASHINGTON, D.C. 20375

DR. P. MANGE
DR. R. MEIER
DR. E. SZUSZCZEWICZ - CODE 4127

DR. J. GOODMAN - CODE 7560

SCIENCE APPLICATIONS, INC.
1250 PROSPECT PLAZA
LA JOLLA, CALIFORNIA 92037

DR. D. A. HAMLIN
DR. L. LINSON
DR. D. SACHS

DIRECTOR OF SPACE AND ENVIRONMENTAL LABORATORY
NOAA
BOULDER, COLORADO 80302

DR. A. GLENN JEAN
DR. G. W. ADAMS
DR. D. N. ANDERSON
DR. K. DAVIES
DR. R. F. DONNELLY

A. F. GEOPHYSICS LABORATORY
L. G. HANSOM FIELD
BEDFORD, MASS. 01730

DR. T. ELKINS
DR. W. SWIDER
MRS. R. SAGALYN
DR. J. M. FORBES
DR. T. J. KENESHEA
DR. J. AARONS

OFFICE OF NAVAL RESEARCH
800 NORTH QUINCY STREET
ARLINGTON, VIRGINIA 22217

DR. H. MULLANEY

COMMANDER
NAVAL ELECTRONICS LABORATORY CENTER
SAN DIEGO, CALIFORNIA 92152

DR. M. BLEIWEISS
DR. I. ROTHMULLER
DR. V. HILDEBRAND
MR. R. ROSE

U. S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER
BALLISTIC RESEARCH LABORATORY
ABERDEEN, MARYLAND

DR. J. HEIMERL

COMMANDER
NAVAL AIR SYSTEMS COMMAND
DEPARTMENT OF THE NAVY
WASHINGTON, D.C. 20360

DR. T. CZUBA

HARVARD UNIVERSITY
HARVARD SQUARE
CAMBRIDGE, MASS. 02138

DR. M. B. MCELROY
DR. R. LINDZEN

PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY PARK, PENNSYLVANIA 16802

DR. J. S. NISBET
DR. P. R. ROHRBAUGH
DR. D. E. BARAN
DR. L. A. CARPENTER
DR. M. LEE
DR. R. DIVANY
DR. P. BENNETT
DR. E. KLEVANS

UNIVERSITY OF CALIFORNIA, LOS ANGELES
405 HILLGARD AVENUE
LOS ANGELES, CALIFORNIA 90024

DR. F. V. CORONITI
DR. C. KENNEL

UNIVERSITY OF CALIFORNIA, BERKELEY
BERKELEY, CALIFORNIA 94720

DR. M. HUDSON

UTAH STATE UNIVERSITY
4TH N. AND 8TH STREETS
LOGAN, UTAH 84322

DR. P. M. BANKS
DR. R. HARRIS
DR. V. PETERSON
DR. R. MEGILL
DR. K. BAKER

CORNELL UNIVERSITY
ITHACA, NEW YORK 14850

DR. W. E. SWARTZ
DR. R. SUDAN
DR. D. FARLEY
DR. M. KELLEY

NASA
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

DR. S. CHANDRA
DR. K. MAEDO

PRINCETON UNIVERSITY
PLASMA PHYSICS LABORATORY
PRINCETON, NEW JERSEY 08540

DR. F. PERKINS
DR. E. FRIEMAN

INSTITUTE FOR DEFENSE ANALYSIS
400 ARMY/NAVY DRIVE
ARLINGTON, VIRGINIA 22202

DR. E. BAUER

UNIVERSITY OF MARYLAND
COLLEGE PARK, MD 20742
DR. K. PAPADOPOULOS
DR. E. OTT

UNIVERSITY OF PITTSBURGH
PITTSBURGH, PA. 15213

DR. N. ZABUSKY
DR. M. BIONDI

DEFENSE DOCUMENTATION CENTER
CAMERON STATION
ALEXANDRIA, VA. 22314

(12 COPIES IF OPEN PUBLICATION
OTHERWISE 2 COPIES) 12CY ATTN TC

UNIVERSITY OF CALIFORNIA
LOS ALAMOS SCIENTIFIC LABORATORY
J-10, MS-664
LOS ALAMOS, NEW MEXICO 87545

M. PONGRATZ
D. SIMONS
G. BARASCH
L. DUNCAN

Massachusetts Institute of Technology
Plasma Fusion Center
Library, NW16-262
Cambridge, MA 02139

LMED

8